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Assessment of organic acid and sugar composition in apricot, plumcot, plum, and peach during fruit development

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Summary

Variation in content of organic acids and soluble sugars, and in physical characteristics was evaluated in apricot (*P. armeniaca* L. cv. Harcot), plumcot (plum-apricot hybrid, *P. salicina* x *P. armeniaca* L. cv. Harmony), plum (*P. salicina* Lindl. cv. Formosa), and peach (*P. persica* L. Batsch cv. Jinmi). The content of organic acids and sugars, as well as parameters of fruit quality (weight, dimensions, firmness, total soluble solids, and total acidity) in *Prunus* fruits during fruit development were determined. Organic acids, including oxalic acid, quinic acid, malic acid, shikimic acid, citric acid, and quinic acid, sugars, including sucrose, fructose, glucose, and sugar alcohol (sorbitol), were identified and quantified using HPLC. Organic acid mostly increased during the early stages of fruit growth (30 - 60 days after full bloom) and decreased until fruits were fully ripened. In general, plum was the highest in most organic acids compared with the other fruits, while apricot contained the lowest acid content except for citric acid. Sucrose, fructose, and glucose content increased with fruit development, unlike content of sorbitol. Plumcot contained the highest fructose, and peach showed the maximum content of sucrose at full maturation stages. Total soluble solids averaged 17.5, 14.8, 11.9, and 10.6 °Brix in apricot, plumcot, plum, and peach, respectively, whereas total acidity was 0.9, 1.4, 0.5, and 0.3% in four *Prunus* cultivars at ripened stages. Shikimic acid was significantly correlated with oxalic acid in apricot, plumcot, and plum, but not in peach. Fructose and glucose were highly correlated in plumcot, plum, and peach.

Introduction

Edible fruit quality is influenced by organic acids and sugars, as well as by changes in color, texture, and flavor because these parameters contribute to organoleptic quality of fruits. The concentrations of organic acids and sugars have an important impact on fruit flavor and quality (BORSANI et al., 2009). Organic acid originally occurs in mitochondria through the tricarboxylic acid cycle, but is located mainly in vacuoles due to catalytic function in the tricarboxylic acid cycle (LÓPEZ-BUCIO et al., 2000). In the early stages of fruit development, fruits accumulate organic acids, and thus have an acidic taste (SHIRATAKE and MARTINOIA, 2007). During the process of fruit maturation and ripening, sugars stored in vacuoles (YAMAKI, 1984) generally increase in concentration along with a simultaneously decrease in organic acids, except in highly acidic fruits such as citrus (ECHEVERRIA and BURNS, 1989). Sugars are synthesized throughout the process of photosynthesis, and used for respiratory substrates and in cell wall structural (YU, 1999). Therefore, total acidity and total soluble solids increase as fruits ripen.

Genus *Prunus* has been commercially grown around the world. Major species are stone fruits, including apricot, plum, and peach. Indeed, plumcot, the interspecific hybrid of apricot and plum, has the potential for commercial production because of its early harvest season and abundant fruit production. The fruit quality of apricot, plumcot, plum, and peach is greatly influenced by the ratio of total acidity to total soluble solids at harvest time because acid and sugar concentrations mainly influence fruit taste. The major acids in *Prunus* fruits are malic acid, citric acid, quinic acid in peach (LE DANTEC et al., 2010), oxalic acid in plum (WU et al., 2011), and tartaric acid, ascorbic acid, shikimic acid, succinic acid, maleic acid, and fumaric acid have also been identified (FLORES et al., 2012). The dominant sugars in stone fruits include fructose, glucose, and sucrose, along with some individual saccharide containing stachyose (SOZZI, 2004), sorbitol (CANTÍN et al., 2009), raffinose (LEDBETTER et al., 2006), rhamnose (KOVÁCS and NÉMETH-SZERDAHELYI, 2002), arabinose, galactose, and xylose (GROSS and SAMS, 1984).

Organic acid and sugar profiles vary depending on the species of stone fruits, which have different qualitative traits. Previous studies reported the composition of organic acids and sugars in apricot, plumcot (AKIN et al., 2008), plum (FAMIANI et al., 2012), and peach (ORAZEM et al., 2011). However, information on the profiles of organic acids and sugars is limited in commercially important *Prunus* fruits during fruit development, maturation, and ripening. Therefore, in this study, the most common and valuable cultivars of apricot, plumcot, plum, and peach were chosen and evaluated. The objective of this study was to investigate the relationship between fruit development and changes in content of organic acids and sugars during the time between full bloom and harvest.

Materials and methods

Plant materials

Four *Prunus* species containing apricot (*Prunus armeniaca* L. cv. Harcot), plumcot (*P. armeniaca* x *P.* salicina L. cv. Harmony), plum (*P. salicina* Lindl. cv. Formosa), and peach (*P. persica* L. Batsch cv. Jinmi) were used in this study. The 'Harmony' plumcot cultivar was originated as a cross between 'Soldam' plum and 'Harcot' apricot (JI HAE and KYEONG HO, 2007), and the appearance of apricot, plumcot, and plum was similar except for ground color (Fig. 1). Four-year-old trees of apricot, plumcot, and plum, and seven-year-old peach trees were grown in the fields of the National Institute of Horticultural and Herbal Science in Rural Development Administration, Suwon, Korea (37°15'N and 126°98'E). The first blossom dates in 2012 were April 20 for apricot and plumcot, April 23 for plum, and April 25 for peach. Six fruits were randomly sampled at two-week intervals beginning 30 days after full blossom for all fruits, and fruit samples were collected, with three replications per fruit cultivar. When fruits started to mature (ripen), fruits were harvested at one-week intervals. The last dates for final harvest were June 26 for apricot, July 3 for plumcot, July 17 for plum, and August 24 for peach.

Fruit quality evaluation

Each fruit was immediately measured for weight, height, diameter, and flesh firmness at each harvest date. Fruit diameter and height were measured by digital calliper (CD-15CPX, Mitutoyo, Kawasaki, Japan). Fruit firmness was measured by Lloyd Instrument TA Plus

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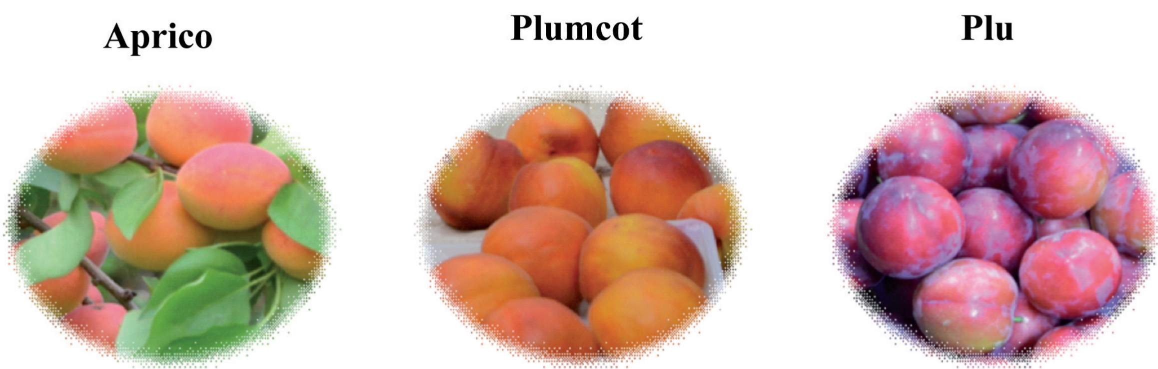

Fig. 1: Fresh fruits of apricot, plumcot, and plum harvested at the stages of maturity.

digital texture analyzer (Ametek, West Sussex, UK). Firmness was expressed as maximum force (gf). Total soluble solids (°Brix) of fruit juice were measured using a hand refractometer PAL-1 meter (Atago, Tokyo, Japan). Total acidity of final-harvest fruits was measured using an automated titrimeter (TitroLine easy, Schott, Mainz, Germany). A mixture of fruit extract and water (1:4 ratio) was titrated to pH 8.1 with 0.1N NaOH solution, and total acidity was expressed as percentage of malic acid.

Sample preparation

Harvested *Prunus* fruits were transported to the laboratory for fresh weight determination. The fruits were cleaned, and seeds were removed. Sections of fresh weighing about 50 g with peel were cut and blended in 40 mL using a household blender for homogenization. The homogenate was centrifuged at 1800 g for 15 min, and supernatant was filtered using Whatman filter papers. The extract was then filtered through a 0.45 µm filter (Acrodisc 25mm syringe filter, Pall Gelman Laboratory, Ann Arbor, MI, USA) before HPLC analysis. All samples were prepared in triplicate.

Organic acid analysis

Organic acid was analyzed by Agilent 1100 high performance liquid chromatography (HPLC) system (Hewlett-Packard 1100 Series) containing quaternary pump, autosampler, and diode array detector with Zorbax SB-Aq C_{18} column (150 mm × 4.6 mm ID, 5µm) (Agilent Technology, Santa Clara, CA. USA). Chromatography separation was performed at 40°C with a flow rate of 0.4 mL/min. The mobile phase was carried out with 1% monopotassium phosphate (KH_2PO_4, pH 2.5). The acid standards were purchased from Sigma-Aldrich (St. Louise, MO, USA), and the detected organic acids were oxalic acid, quinic acid, malic acid, shikimic acid, citric acid, and fumaric acid. Absorbance was measured at 214 nm.

Soluble sugar analysis

Sucrose, fructose, glucose, and sorbitol standards were purchased from Sigma-Aldrich (St. Louise, MO, USA). Sugars were separated and quantified by HPLC analysis. The HPLC system (YoungLin, Anyang, Korea) contained a quaternary pump, an autosampler, and a reflective index detector with Sugar-Pak^{TM}1 column (6.5 × 300 mm, Waters, USA) at 90 °C with a flow rate 0.5 mL/min. The mobile phase was performed with an isocratic elution of ultrapure water for peak separation.

Statistical analysis

Data was analyzed with ANOVA using SAS statistical software. Means were separated using the Duncan's multiple range test at confidence level $P \leq 0.05$, and Pearson correlation coefficients were calculated. Data was presented as the mean ± standard deviation of triplicate.

Results and discussion

Fruit quality

Fruit weight, height, width, and firmness affected fruits quality. The quality parameters were measured during fruit development and maturation, and required characteristics in marketable fruit yields. Changes during fruit maturation in apricot, plumcot, plum, and peach were shown in Tab. 1. Fruit weight, height, and width accumulatively increased from 30 days after full bloom until 65 days after full bloom in apricot, 72 days after full bloom in plumcot, 91 days after full bloom in plum, and 123 days after full bloom in peach. Fruit weight rapidly and linearly increased with fruit growth and maturity. Apricot was continuously larger in fruit weight, height, and width than plumcot and plum from the first onset of fruits to the end of fruit harvest. The hybrid plumcot species was in the middle position for fruit growth between apricot and plum. Peach developmental changes markedly increased after 72 days after full bloom because fruit growth duration was longer than for apricot, plumcot, and plum. In general, fruit firmness linearly decreased until 65 days after full bloom, and then slightly declined after that with final growth. Peach firmness was much harder than other fruits throughout the fruit development process. Since firmness is associated with water content of fruits and structural rigidness of cell walls, fruit firmness decreased between the initial fruit developmental stage and harvest.

Total acidity and total soluble solids are also important factors in evaluation of fruit quality at harvest time. Total soluble solids (°Brix) dramatically increased in plumcot and apricot until final ripening stages. Maximum total soluble solids were found in apricot (17.5°Brix) followed by plumcot (14.8°Brix), peach (12.3°Brix), and plum (11.9°Brix) at the final harvest stages. During fruit development and ripening, the patterns of increasing total soluble solids were related to decreased total acidity. Total acidity increased between 30 days after full bloom and 44 days after full bloom, and then decreased with fruit development in apricot, plumcot, and plum, while total acidity in peach showed a gradual reduction through fruit development. The least total acidity was determined in peach (0.2%), followed by plum (0.5%), apricot (0.9%), and plumcot (1.4%).

Organic acid analysis

Oxalic acid, quinic acid, malic acid, shikimic acid, citric acid, and fumaric acid are important organic acids in *Prunus* fruits. Oxalic acid in apricot, plumcot, plum, and peach decreased from 30 days after full bloom until fruit was fully ripened at final harvest time

Tab. 1: Fresh weight, size, firmness, and quality of four *Prunus* fruits during fruit maturity.

Fruits	DAFB[a]	Weight (g)	Height (mm)	Width (mm)	Firmness (gf)	TSS[b] (Brix)	Total acidity (%)
Apricot	30	20.7 ± 0.6 c	35.8 ± 0.1 c	33.7 ± 0.1 c	-		
	44	35.8 ± 3.0 b	40.6 ± 0.1 b	36.5 ± 0.1 c	7.2 ± 0.2 a		
	58	63.1 ± 4.9 a	46.7 ± 1.5 a	45.6 ± 1.1 b	3.0 ± 0.2 b		
	65[c]	72.7 ± 5.6 a	49.2 ± 1.1 a	48.7 ± 1.6 a	0.5 ± 0.1 c	17.5 ± 1.0	0.9 ± 0.1
Plumcot	30	14.0 ± 0.9 c	31.1 ± 0.1 b	28.7 ± 0.1 c	-		
	44	21.1 ± 0.9 c	33.2 ± 0.1 b	30.7 ± 0.1 c	8.7 ± 0.3 a		
	58	45.7 ± 3.5 b	44.3 ± 1.5 a	41.7 ± 0.5 b	4.1 ± 0.3 b		
	65	59.1 ± 2.8 a	44.6 ± 0.7 a	45.5 ± 0.9 a	1.9 ± 0.1 c		
	72[c]	70.3 ± 8.9 a	47.1 ± 1.4 a	47.3 ± 2.1 a	0.6 ± 0.1 d	14.8 ± 0.5	1.4 ± 0.1
Plum	30	5.7 ± 0.0 e	27.0 ± 0.0 e	21.5 ± 0.1 e	-		
	44	15.9 ± 1.5 de	33.9 ± 0.2 d	28.2 ± 0.1 d	8.7 ± 0.2 a		
	58	30.0 ± 5.9 d	40.2 ± 2.5 c	36.7 ± 2.1 c	5.6 ± 0.4 b		
	65	56.1 ± 6.0 c	46.1 ± 2.7 b	46.8 ± 1.5 b	1.8 ± 0.2 c		
	79	81.3 ± 6.0 b	52.6 ± 1.9 a	52.9 ± 1.9 a	1.1 ± 0.1 cd		
	86	82.9 ± 5.2 b	52.5 ± 2.2 a	52.0 ± 1.7 a	0.5 ± 0.2 d		
	91[c]	103.2 ± 8.8 a	56.1 ± 2.1 a	54.7 ± 2.1 a	0.4 ± 0.1 d	11.9 ± 0.8	0.5 ± 0.1
Peach	30	3.4 ± 0.5 f	24.4 ± 1.3 g	18.6 ± 1.1 f	-		
	44	24.0 ± 3.8 ef	41.8 ± 2.0 f	30.5 ± 2.1 e	-		
	58	39.0 ± 2.4 e	43.5 ± 1.1 f	35.3 ± 1.2 e	16.1 ± 3.3 a		
	72	54.0 ± 4.0 de	49.3 ± 1.7 e	42.2 ± 0.5 d	11.7 ± 1.9 a		
	86	80.7 ± 1.0 d	54.3 ± 0.2 d	50.4 ± 1.4 c	4.1 ± 0.5 c		
	100	127.3 ± 0.2 c	59.6 ± 1.1 c	60.4 ± 0.7 b	3.3 ± 0.2 cd		
	114	209.2 ± 27.9 b	68.4 ± 1.9 b	70.3 ± 4.5 a	2.6 ± 0.2 cd		
	123[c]	307.1 ± 10.6 a	84.2 ± 0.6 a	74.2 ± 3.2 a	1.7 ± 0.1 d	10.6 ± 0.2	0.3 ± 0

[a]DAFB: Days after full bloom
[b]TSS: total soluble solid
[c]Last day of fruit harvest
Data is means ± standard deviation. Means followed by different letters in the same column for the same species are significantly different at $P \leq 0.05$

(Tab. 2). Quinic acid, malic acid, and shikimic acid increased and then dramatically decreased after 44 days after full bloom. Quinic acid is the major acid in plum at the early stage of fruit growth, and malic acid is especially abundant in plumcot during fruit maturity. Concentration of citric acid in apricot rose considerably from 30 to 44 days after full bloom, and then continuously increased during fruit development and maturity. However, citric acid was much lower in plum, followed by peach, compared with plumcot and apricot. A previous study showed that malic acid, citric acid, quinic acid, and shikimic acid are major acids in peach (*Prunus davidiana*) (Wu et al., 2005). Generally, concentration of organic acid is higher at early stages of fruit development than at fruit maturity.

Soluble sugar content

Sugar profiles indicated the sweet taste of *Prunus* fruits. Major sugars (sucrose, glucose, fructose, and sorbitol) were detected and concentration was determined in apricot, plumcot, plum, and peach during fruit maturation (Tab. 3). Sugar content was variable among fruits. Due to differences in fruit growth and duration. Sucrose content was the highest at the final stage of harvest in apricot apricot (1710 µg/g), plum (2828 µg/g), and peach (6761 µg/g). However, sucrose was at a peak at 58 days after full bloom in plumcot (2478 µg/g), and then declined until the final stages. Sucrose in apricot and plum was detected only when fruits reached full maturation. The content of glucose and fructose was higher than sucrose and sorbitol during fruit growth. Plumcot contained the highest glucose (4302 µg/g) and fructose (4374 µg/g) at the final harvest stage Many studies have compared sugar content, mostly glucose, fructose, and sucrose, in berry (Mikulic-Petkovsek et al., 2012), mandarin (Zhang et al., 2012) and peach (Wu et al., 2012). The sugar composition mostly makes *Prunus* fruits sweet taste.

Correlations

Correlation coefficients between organic acid and sugar content showed various relationships (Tab. 4). Individual organic acids and sugar was related positively, negatively, or insignificantly. Oxalic acid and malic acid were strongly correlated with shikimic acid in apricot and plumcot. Oxalic acid and quinic acid were highly related in plumcot ($r = 0.89$) and plum ($r = 0.96$). In peach, malic acid and fumaric acid were positively correlated ($r = 0.93$). Citric acid was significantly correlated with fumaric acid only in plum ($r = 0.98$, $P \leq 0.01$). Quinic acid and malic acid were negatively correlated in plum and peach. Sucrose content was correlated with glucose and fructose in apricot and peach, respectively. Fructose was highly correlated with glucose in plumcot, plum, and peach ($r = 0.90$, $r = 0.99$, and $r = 0.76$, respectively).

Conclusion

The content of each organic acid and sugar variable changes during fruit growth and maturity (increasing in days after full bloom) in apricot, plumcot, plum, and peach. Determination of organic acid and sugar profile in main stone fruits can benefit further Prunus breeding lines with particular interest of organic acid and sugar composition.

Tab. 2: Changes in content of organic acids in apricot, plumcot, plum, and peach during fruit maturation.

Fruits	DAFB[a]	Oxalic acid	Quinic acid	Malic acid	Shikimic acid	Citric acid	Fumaric acid
Apricot	30	88 ± 0.9	230 ± 21.4	2945 ± 27.1	57 ± 0.9	236 ± 9.5	1 ± 0.1
	44	54 ± 8.7	195 ±17.6	2312 ± 232.5	33 ± 0.4	1451 ± 31.8	1 ± 0.1
	58	38 ± 5.0	132 ± 11.5	815 ± 73.9	17 ± 0.7	1953 ± 36.8	4 ± 0.2
	65[b]	28 ± 2.4	232 ± 24.0	702 ± 28.4	8 ± 2.3	1240 ± 93.5	5 ± 0.5
Plumcot	30	89 ± 4.1	1051 ± 35.7	3348 ± 112.9	37 ± 2.1	59 ± 9.1	2 ± 0.5
	44	77 ± 13.1	1149 ±171.1	4270 ± 260.0	41 ± 1.1	289 ± 22	1 ± 0.1
	58	53 ± 4.8	603 ± 25.2	3281 ± 42.6	31 ± 2.4	677 ± 52.5	1 ± 0.1
	65	59 ± 9.4	583 ± 182.9	3527 ± 515.6	27 ± 4.8	996 ± 213.1	2 ± 0.3
	72[b]	22 ± 0.8	405 ± 19.5	1987 ± 23.7	12 ± 2.8	548 ± 41	2 ± 0.1
Plum	30	224 ± 5.6	2751 ± 87.8	1728 ± 39.2	68 ± 1.9	28 ± 6.8	1 ± 1.2
	44	38 ± 7.6	1481 ± 92.1	2059 ± 131.6	52 ± 4.4	30 ± 0.2	1 ± 0.1
	58	22 ± 4.8	563 ± 89.3	2332 ± 147.1	35 ± 2.8	31 ± 5.1	1 ± 0.2
	65	28 ± 3.3	377 ± 49.8	1926 ± 31.5	23 ± 0.4	32 ± 2.8	1 ± 0.2
	79	23 ± 5.2	438 ± 22.0	2040 ± 208.9	26 ± 3.0	42 ± 1.1	3 ± 0.2
	86	26 ± 5.6	438 ± 74.5	1984 ± 150.8	27 ± 1.9	40 ± 8.7	3 ± 0.4
	91[b]	224 ± 0.3	2751 ± 42.2	1728 ± 36.5	68 ± 0.4	28 ± 9.8	1 ± 0.1
Peach	30	41 ± 0.9	972 ± 22.4	597 ± 15.9	26 ± 0.6	71 ± 0.6	5 ± 0.1
	44	46 ± 8.0	1858 ± 223.5	398 ± 74.5	23 ± 4.7	31 ± 6.9	3 ± 0.5
	58	49 ± 5.7	1633 ± 195.3	195 ± 87.3	15 ± 3.5	62 ± 13.0	0 ± 0.2
	72	26 ± 2.1	2487 ± 142.9	0	16 ± 0.4	133 ± 7.2	0 ± 0.1
	86	53 ± 12.0	1734 ± 66.5	216 ± 6.8	18 ± 1.2	220 ± 18.0	1 ± 0.1
	100	76 ± 12.0	1163 ± 66.5	272 ± 6.8	18 ± 1.2	308 ± 54.6	2 ± 0.8
	114	59 ± 9.9	481 ± 189.4	352 ± 40.8	12 ± 1.6	178 ± 12.7	2 ± 0.1
	123[b]	51 ± 11.2	497 ± 58.8	558 ± 139.5	12 ± 0.5	126 ± 7.4	3 ± 0.5

[a]DAFB: Days after full bloom
[b]Last day of fruit harvest
Data is means ± standard deviation

Tab. 3: Content of sucrose, fructose, glucose, and sorbitol in apricot, plumcot, plum, and peach during fruit maturation. Each point indicates mean standard deviation.

Fruits	DAFB[a]	Sucrose	Glucose	Fructose	Sorbitol
Apricot	30	0	3045 ± 56.1	1071 ± 20.6	1034 ± 20.3
	44	0	3261 ± 142.2	1213 ± 250.4	1188 ± 164.8
	58	0	2479 ± 324.2	1687 ± 185.7	1185 ± 222.3
	65[b]	1710 ± 364.9	4142 ± 241.6	3588 ± 218.7	261 ± 152.8
Plumcot	30	0	1552 ± 267.7	1010 ± 129.9	921 ± 166.0
	44	0	2466 ± 244.0	1483 ± 73.6	1748 ± 141.9
	58	2478 ± 155.7	2367 ± 243.0	2256 ± 164.0	2144 ± 325.5
	65	1062 ± 393.6	2562 ± 245.8	3155 ± 205.5	2183 ± 214.5
	72[b]	332 ± 113.1	4302 ± 108.8	4374 ± 114.1	237 ± 70.3
Plum	30	0	1176 ± 79.6	1456 ± 58.9	217 ± 18.0
	44	0	1799 ± 128.9	2067 ± 133.2	308 ± 55.4
	58	0	3018 ± 201.6	3010 ± 218.3	227 ± 109.4
	65	0	3123 ± 203.4	3382 ± 408.9	272 ± 44.4
	79	0	3188 ± 89.7	3421 ± 98.5	516 ± 29.2
	86	2242 ± 217.1	3721 ± 103.0	3693 ± 421.0	232 ± 107.5
	91[b]	2728 ± 99.4	3432 ± 96.2	3423 ± 134.9	335 ± 15.7
Peach	30	0	2103 ± 40.0	2242 ± 41.6	388 ± 8.6
	44	574 ± 231.8	1795 ± 339.9	1897 ± 371.4	452 ± 66.5
	58	1097 ± 463.8	1356 ± 244.3	1428 ± 238.3	393 ± 44.1
	72	965 ± 156.6	1586 ± 150.7	1678 ± 245.6	631 ± 83.4
	86	1542 ± 114.0	1654 ± 175.2	1570 ± 108.0	637 ± 67.2
	100	3060 ± 238.9	1734 ± 191.2	965 ± 75.5	1066 ± 65.4
	114	4592 ± 153.7	2223 ± 263.9	1764 ± 136.8	1344 ± 268.5
	123[b]	6761 ± 252.8	3432 ± 246.3	2563 ± 146.9	653 ± 62.4

[a]DAFB: Days after full bloom
[b]Last day of fruit harvest
Data is means ± standard deviation

Tab. 4: Correlation matrix between organic acids and sugars in four *Prunus* cultivars.

	Oxalic acid	Quinic acid	Malic acid	Shikimic acid	Citric acid	Fumaric acid	Sucrose	Fructose	Glucose
Apricot									
Quinic acid	0.340								
Malic acid	0.940*	0.401							
Shikimic acid	0.996**	0.319	0.961*						
Citric acid	-0.804	-0.790	-0.729	-0.771					
Fumaric acid	-0.849	-0.196	-0.960	-0.889	0.511				
Sucrose	-0.609	0.496	-0.594	-0.643	0.018	0.727			
Fructose	-0.330	0.770	-0.198	-0.341	-0.229	0.323	0.878		
Glucose	-0.750	0.288	-0.761	-0.785	0.212	0.860	0.973*	0.760	
Sorbitol	0.479	-0.596	0.493	0.522	0.136	-0.663	-0.986*	-0.885	-0.936
Plumcot									
Quinic acid	0.897*								
Malic acid	0.800	0.769							
Shikimic acid	0.931*	0.896*	0.914*						
Citric acid	-0.535	-0.736	-0.150	-0.462					
Fumaric acid	-0.290	-0.500	-0.531	-0.595	0.353				
Sucrose	-0.293	-0.508	-0.050	-0.098	0.616	-0.222			
Fructose	-0.926*	-0.705	-0.727	-0.882*	0.350	0.285	-0.058		
Glucose	-0.943*	-0.903*	-0.759	-0.956*	0.643	0.542	0.156	0.909*	
Sorbitol	0.349	0.140	0.720	0.530	0.492	-0.355	0.596	-0.510	-0.324
Plum									
Quinic acid	0.961**								
Malic acid	-0.874*	-0.816*							
Shikimic acid	0.888**	0.972**	-0.665						
Citric acid	-0.532	-0.624	0.282	-0.700					
Fumaric acid	-0.557	-0.666	0.290	-0.749	0.985**				
Sucrose	-0.413	-0.499	0.211	-0.560	0.953**	0.957**			
Fructose	-0.969**	-0.961**	0.841*	-0.904**	0.674	0.693	0.571		
Glucose	-0.972**	-0.982**	0.866*	-0.927**	0.623	0.649	0.505	0.991**	
Sorbitol	-0.279	-0.413	0.127	-0.477	-0.044	0.102	-0.080	0.250	0.322
Peach									
Quinic acid	-0.556								
Malic acid	0.204	-0.751*							
Shikimic acid	-0.197	0.238	0.342						
Citric acid	0.678	-0.181	-0.269	-0.315					
Fumaric acid	0.128	-0.581	0.931*	0.546	-0.255				
Sucrose	0.450	-0.710	0.306	-0.724*	0.363	0.126			
Fructose	0.100	-0.722	0.698	-0.279	-0.035	0.573	0.799*		
Glucose	-0.462	-0.379	0.682	0.096	-0.575	0.596	0.287	0.765*	
Sorbitol	0.618	-0.470	-0.099	-0.528	0.706	-0.122	0.577	0.159	-0.334

*and ** indicate significant difference at * $P \leq 0.05$, ** $P \leq 0.01$.

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